

Musical Notation & Representation

Music 253/CS 275a

Stanford University

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9 Jan 2018

Representing Music

- For **Performance** (used as memory aid and for non-aural transmission)

Usually not a complete representation (some discretion left to performer)

- Usually written, but also Guidonian hand is a spatial representation of music for education and memorization.

- For **Analysis**

Usually highlights a specific aspect of the music (reductive)

- Graphical representations (visualizations)
- Digital representations (computational analysis)
- Audio-based analysis (such as spectrograms)

Oldest Known Music Notation

Old Babylonian cuneiform musical notation. 2000-1700 BC



2 double columns, each of 7 ruled lines with numbers in Old Babylonian cuneiform tablature notation, with headings, "intonation" and "incantation", respectively.

Two ascending 7-note scales to be played on a 4-stringed lute tuned in ascending fifths.



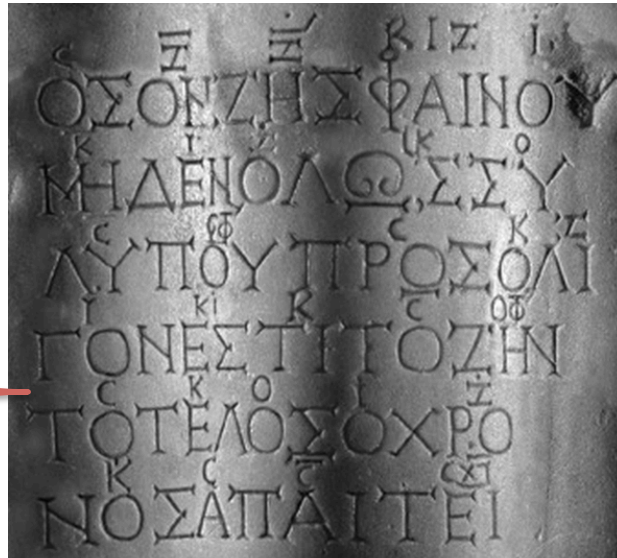
http://www.schoyencollection.com/music_files/ms5105.jpg

<http://www.schoyencollection.com/music.html>

Music Notation in Ancient Greece

Oldest complete notated song (~1st century AD)

Seikilos epitaph



\bar{C} \bar{Z} $\dot{\bar{Z}}$ K I Z $\dot{\bar{I}}$
 Ὅ σον ζῆς φαί νου

\bar{K} I $\dot{\bar{Z}}$ $\dot{\bar{K}}$ O \bar{C} $\dot{\bar{O}}$ Φ
 μη δέν ὄ λως σὺ λυ ποῦ

\bar{C} K Z I $\dot{\bar{K}}$ I K \bar{C} $\dot{\bar{O}}$ Φ
 πρὸς ὀ λί γον ἐς τὶ τὸ ζῆν

\bar{C} K O I $\dot{\bar{Z}}$ $\dot{\bar{K}}$ \bar{C} \bar{C} $\dot{\bar{X}}$ $\dot{\bar{T}}$
 τὸ τέ λος ὀ χρό νος ἀπ αι τεῖ.

Music Notation in Ancient Greece

C Z̄ Ż K I Z İ

Ὁ σον ζῆς φαί νου
While you live, shine

K̄ I Ż İ K̄ O C̄ Ȯ Φ

μη δέν ὅ λως σὺ λυ ποῦ
Have no grief at all

C K Z İ K̄ İ K̄ C̄ Ȯ Φ

πρὸς ὀ λί γον ἐσ τὶ τὸ ζῆν
Life exists only for a short while

C K O İ Ż K̄ C C̄ C̄ Ẋ Ṫ

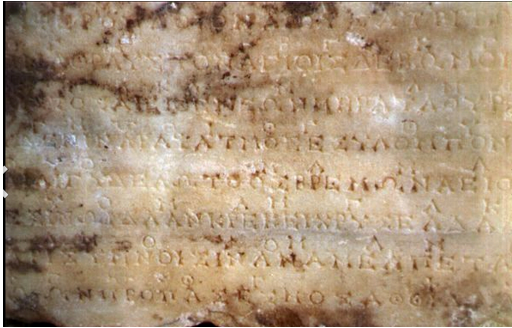
τὸ τέ λος ὁ χρό νος ἀπ αι τεῖ.
And time demands its toll



http://en.wikipedia.org/wiki/Seikilos_epitaph

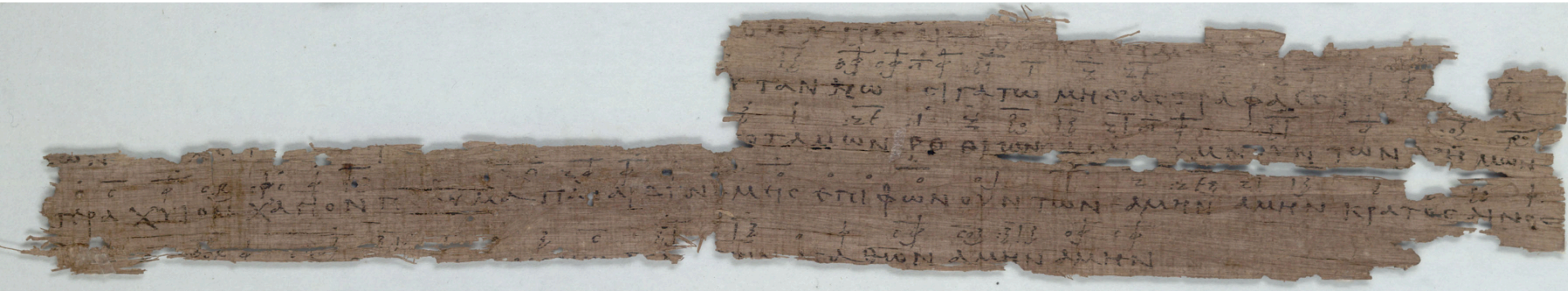
Performed on a *hydraulis*: https://www.youtube.com/watch?v=P4_iWkP24Ww#t=7

Music Notation in Ancient Greece



2nd century BC
Earliest surviving composition
with a known composer
(Athenios son of Athenios)

http://en.wikipedia.org/wiki/Delphic_Hymns



http://en.wikipedia.org/wiki/Oxyrhynchus_hymn

3rd century AD

http://en.wikipedia.org/wiki/Music_of_ancient_Greece

Tonic Sol-Fa

The Lamb.

WILLIAM BLAKE.

GEORGE HENSCHEL.

VOICE.

Lit - tle lamb, who made thee? Dost thou know who

KEY C. { | m .m :m .s | s :r | m .s :d' .l }

PIANO.

The image shows a musical score for the song 'The Lamb' by William Blake, set to music by George Henschel. The score is for voice and piano. The voice part is written on a single staff with a treble clef and a 2/4 time signature. The piano part is written on a grand staff with both treble and bass clefs and a 2/4 time signature. The lyrics are 'Lit - tle lamb, who made thee? Dost thou know who'. Below the lyrics is a Tonic Sol-Fa notation: KEY C. { | m .m :m .s | s :r | m .s :d' .l }. The notation uses letters m, s, r, d' to represent musical notes.

Byzantine Music Notation

(10th – 15th centuries)

interval notation



Romania, 1823

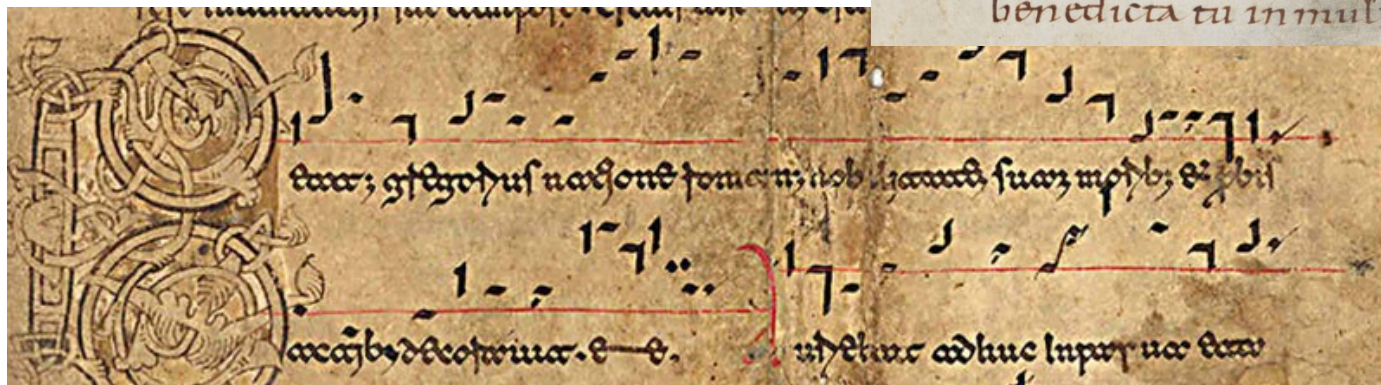
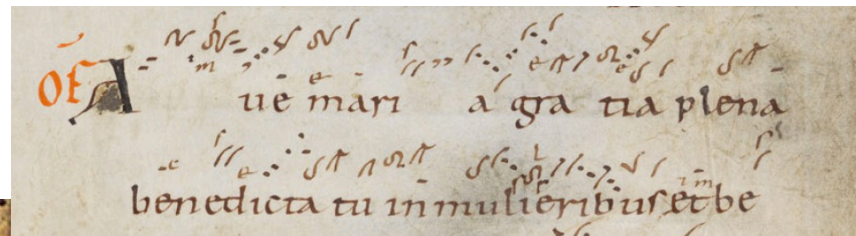
http://en.wikipedia.org/wiki/Musical_notation#Byzantine_Empire

Δεῦ - τε πό - μα πί - ω - μεν και - νόν' οὐκ ἐκ πέ - τρας

Deū - τε πό - μα πί - ω - μεν και - νόν' οὐκ ἐκ πέ - τρας

http://www.musicportal.gr/byzantine_music_system/?lang=en

Gregorian Chant



http://www.schoyencollection.com/music_files/ms1681.jpg

Comm. I.

E C-CE virgo concí-pi- et, et pá- ri- et fi- li-

← Messine notation

Modern chant notation

← St. Gall notation

<http://euouae.com/category/transcription/>

http://en.wikipedia.org/wiki/Gregorian_chant

<http://en.wikipedia.org/wiki/Neume>



Shape Notes



16 STAR IN THE EAST 10, 11. Baptist Harmony, p. 35

Hail the blest morn, see the great Mediator,
 Shepherds, go worship the babe in the manger,
 Down from the regions of glory descend!
 Lo, for his guard the bright angels attend. } **CHORUS.**
 Brightest and best of the sons of the morning!

fa so la fa so la mi

Dawn on our darkness, and lend us thine aid;
 Star in the east, the ho - ri - zon a - dorn - ing, Guide where our infant Re - deemer was laid.

2 Cold on his cradle the dew-drops are shining;
 Low lies his bed, with the beasts of the stall;
 Angels adore him, in slumbers reclining,
 Wise men and shepherds before him do fall.
 Brightest and best. &c.

3 Say, shall we yield him, in costly devotion,
 Odours of Eden, and offerings divine,
 Gems from the mountain, and pearls from the ocean,
 Myrrh from the forest, and gold from the mine?
 Brightest and best. &c.

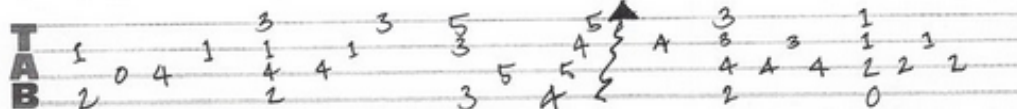
4 Vainly we offer each ample oblation,
 Vainly with gold we his favour secure,
 Richer by far is the heart's adoration:
 Dearest to God are the prayers of the poor
 Brightest and best. &c.

Tablature

Indicates *how* to play the pitches, not an abstracted/neutral concept of pitch.

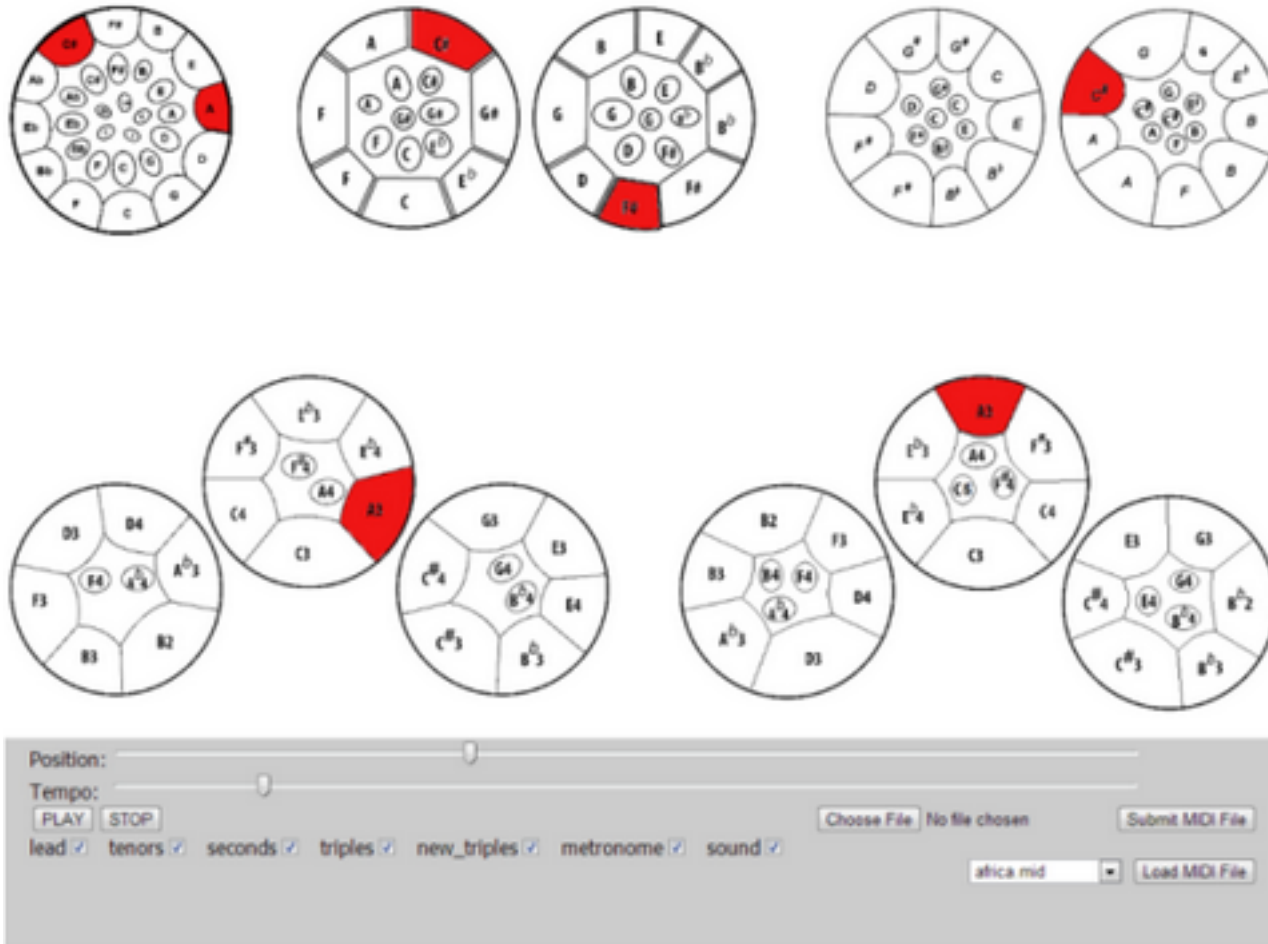


lute



E - 5 - 3 - - - 5 - 3/5 - - -
B - - 7 - - 7 - - - 7 - - - 7 - -
G - - - - 7 - 7 - 0 - - 0 - 7 - 7 -
D - 0 - - 0 - - - - - - - - -
A 0 - - - - - - - - - - - -
E - - - - - - - - - - - -

Steel Drum Tablature



— Jonathan Potter, Cardinal Calypso

Koto Tablature

Yamada school notation (Tokyo)

テ - ン | トン シャン | シヤ シヤ | コ ロ トン トン | トン コ ロ | リン シヤッ
 五 - | 参 { 色 | 〇 { 参 { 参 | ハ、セ六七 | 参 五、四 | 参 { 色

“Rokudan no shirabe”

by Kengyō Yatsuhashi (1614–1685)

Digital representation:



<https://www.youtube.com/watch?v=u26SG0015dc>

|| 5 - 3 1 | 〇 3̣3̣8̣.7̣6̣7̣ | 1 5̣.4̣3̣ 1 | 9 8̣7̣8̣.7̣6̣7̣ |



**koto	**kuchi	**kern
*M4/4	*M4/4	*M4/4
=1-	=1-	=1-
{5+i	te	{2d
-	n	.
3	ton	4A
1s	shan	4d: 4G:
=2	=2	=2
0}	.	4r}
{3 sb	sha	{8A: 8A#:
3 sc	sha	8A: 8A#:
8 .	koo	8.a
7	ro	16g
6	rin	8d#
7 o	chin	16gH
.	.	16ah
=3	=3	=3
1c	ton	4d
5 .	koo	8.d
4	ro	16A#
3}	rin	4A}
{1s	shan	{4d: 4G:
=4	=4	=4

Ikuta school notation (Kyoto)

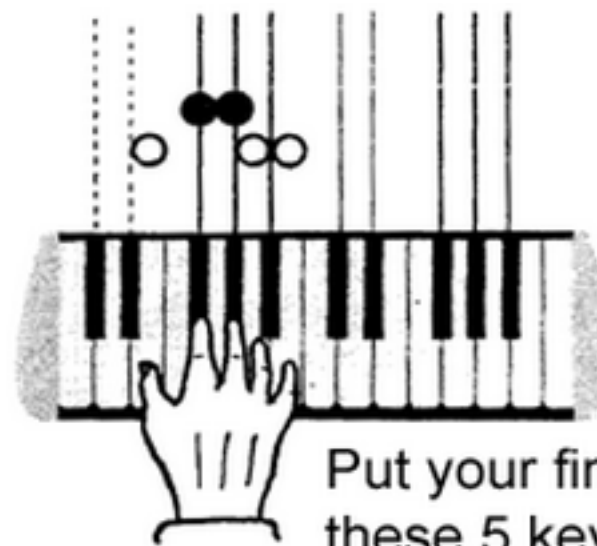
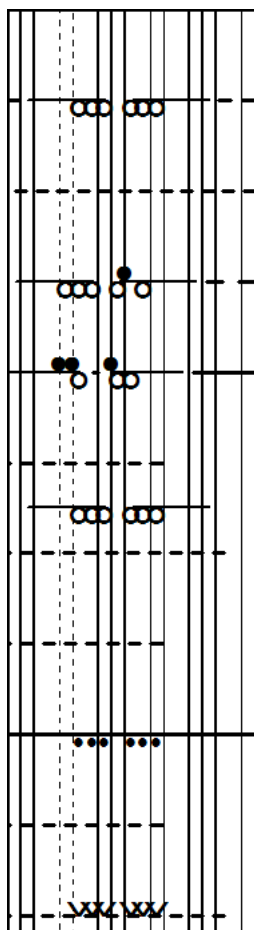
テ 五
 北 〇
 シ 三
 シ 二
 一 〇
 ヤ
 シ 三 四 二
 シ 三 三
 コ ハ
 ト 一
 ロ 六
 リ 六
 ナ 七
 ト 一 三
 シ 五
 ト 三
 シ 二
 シ



Piano Tablature

Klavarskribo

“Keyboard script” in Esperanto



Put your fingers above
these 5 keys

<https://www.youtube.com/watch?v=MlolvxunihA&t=659>

<http://evanlenz.net/blog/2007/11/02/re-discovering-klavarskribo/>

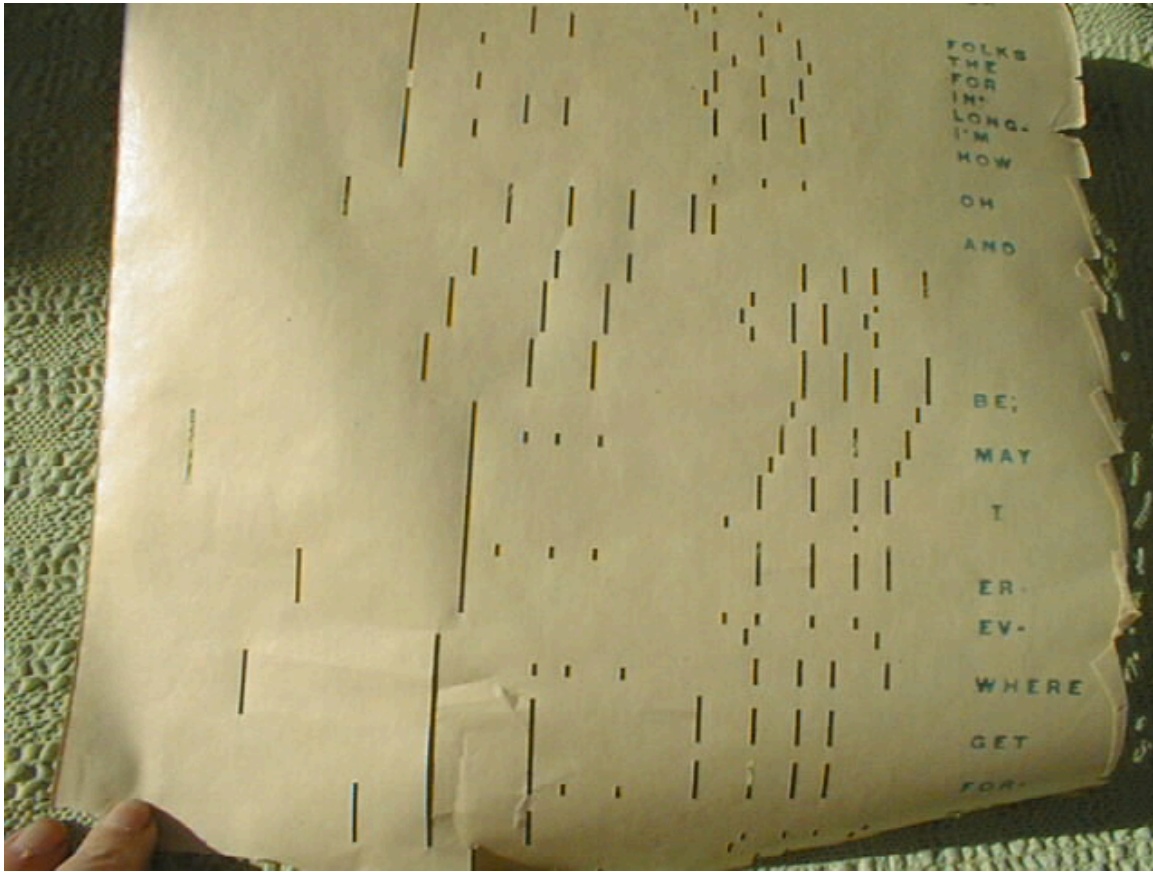
<http://en.wikipedia.org/wiki/Klavarskribo>

<http://www.klavarskribo.nl/en>

Piano Rolls

Mechanical Representation of music

<http://pianoroll.sapp.org/full-rolls-set2>



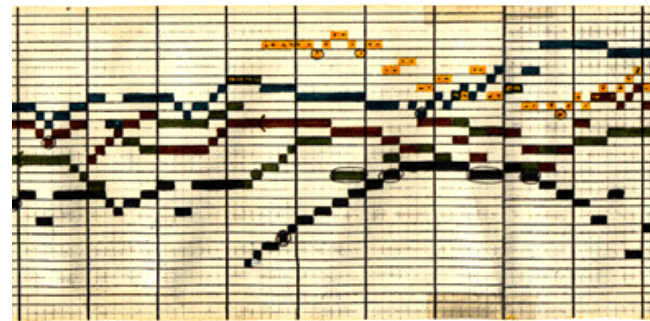
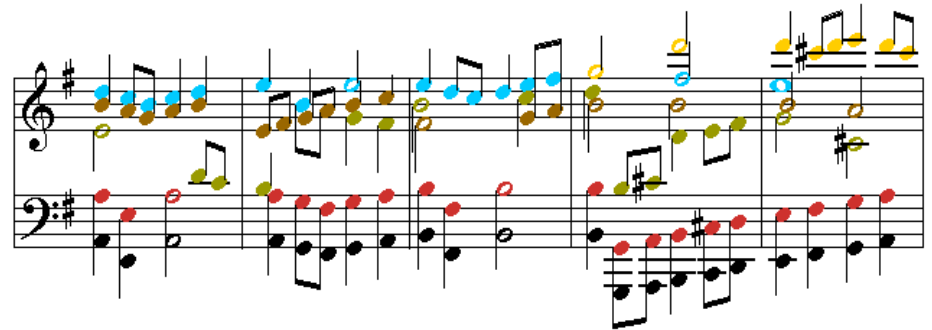
http://en.wikipedia.org/wiki/Piano_roll

<https://www.youtube.com/watch?v=GjpPesy7kIA>

Music Animation Machine

<http://www.musanim.com>

Stephen Malinowski



<https://www.youtube.com/channel/UC2zb5cQbLabj3U9l3tke1pg>

<https://www.youtube.com/playlist?list=PLMOarqHv8B7P1BuvL2iGqkjS1xNrvTiuX>

Music Animation Machine

Bach, Toccata and Fugue in D minor, organ

https://www.youtube.com/watch?v=ipzR9bhei_o

Mozart, Symphony No. 40 in G minor

<https://www.youtube.com/watch?v=Vh-7NZbg65M>

Beethoven, Fur Elise

<https://www.youtube.com/watch?v=gD-OMO1pDNk>

Beethoven, String Quartet No. 16, 1st mvt. (opus 135)

<https://www.youtube.com/watch?v=Lj4kLPgX5QM>

Paganini, Caprice No. 5 (solo violin)

<https://www.youtube.com/watch?v=xhc1PsokFOw>

Debussy, First Arabesque

<https://www.youtube.com/watch?v=Yt1jfX5C1u0>

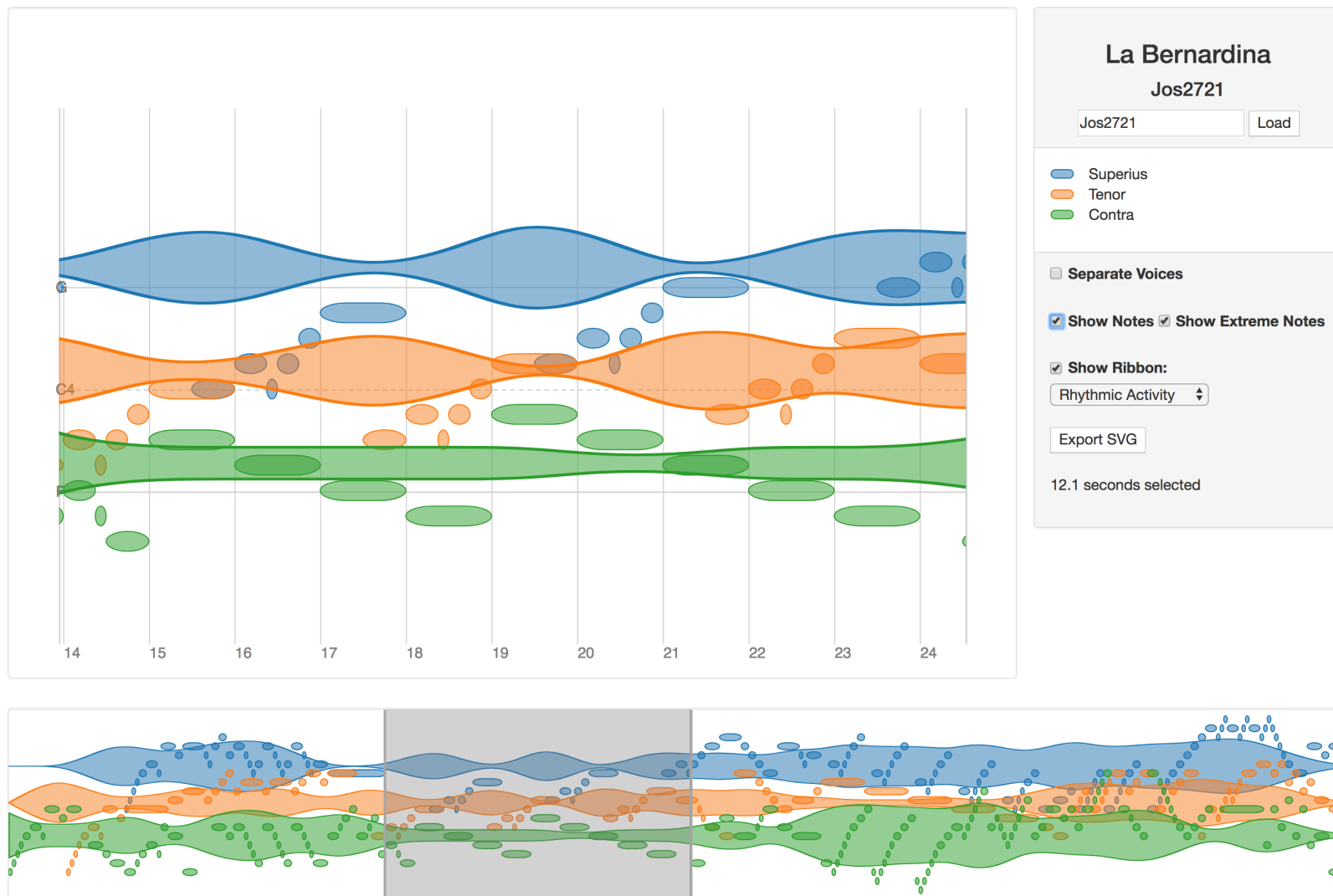
Vivaldi, Winter from Four Seasons

<https://www.youtube.com/watch?v=Qqe0GdUpJHs>

How are musical
Dimensions mapped
In each visualization?

Josquin Research Project

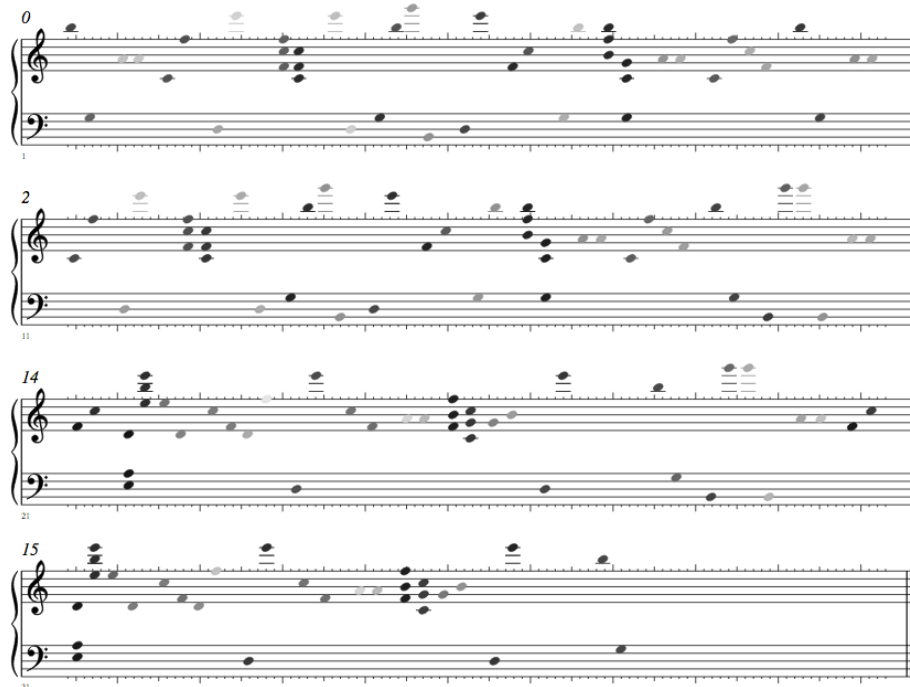
<http://ribbon.humdrum.org>



Performance Data Visualization

Webern Piano Variations, mvmt. 2, (Op. 27)

Anderszewski 1996



Gould 1954



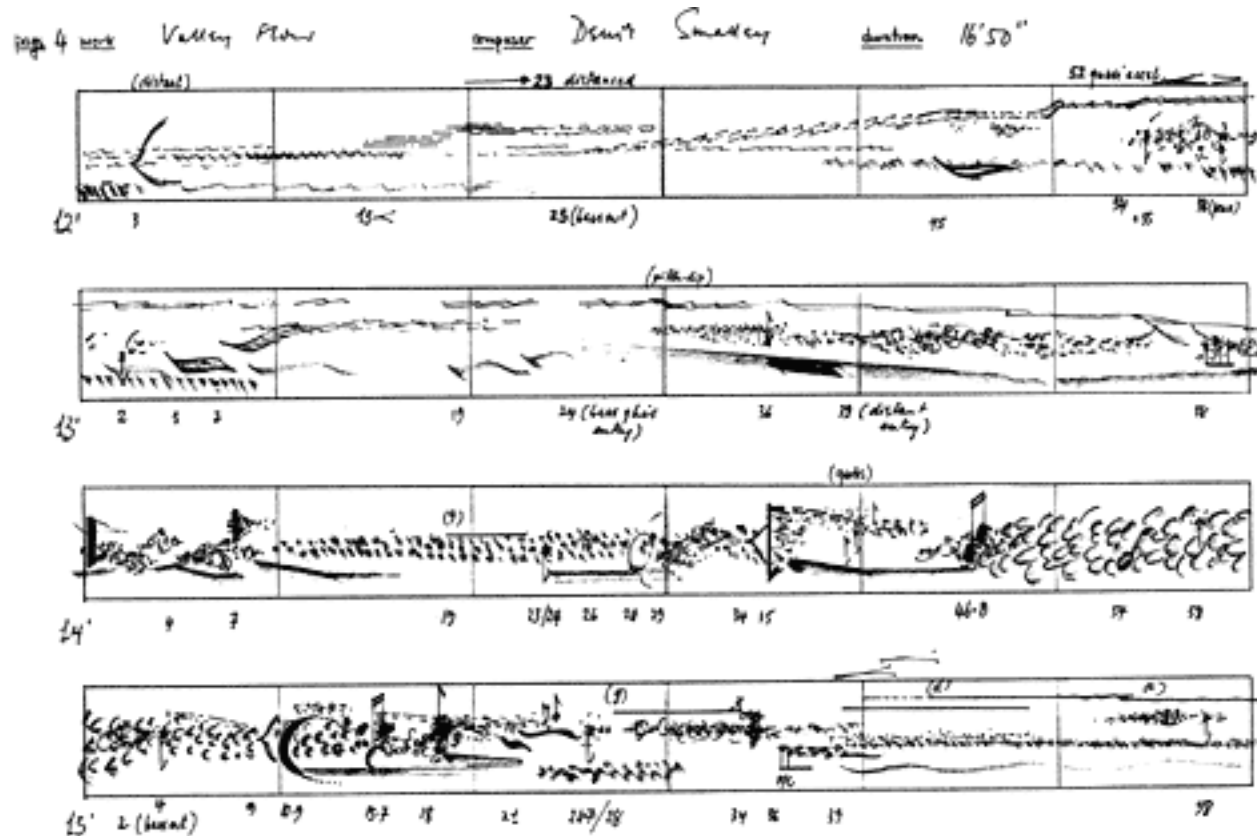
<http://dl.acm.org/citation.cfm?id=2597179>

<http://mazurka.org.uk/webern/notation/Anderszewski1996>

<http://mazurka.org.uk/webern/notation/Gould1954>

Textural Notation

Analytic notation of electro-acoustic music

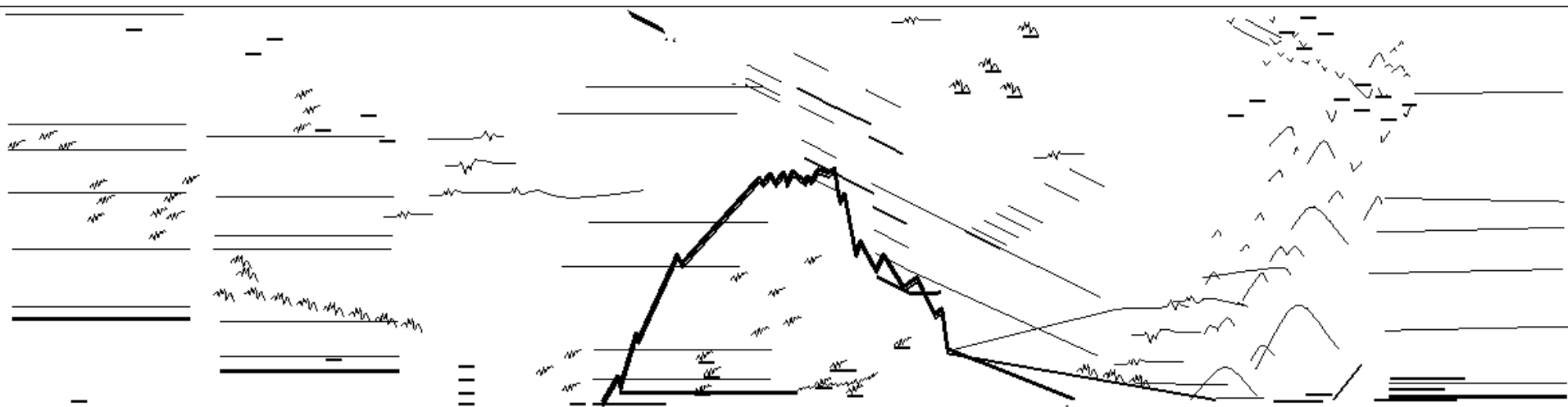


line2sine

Sonification of vector graphics

<http://sig.sapp.org/projects/all/line2sine/line2sine/examples>

Example 6:



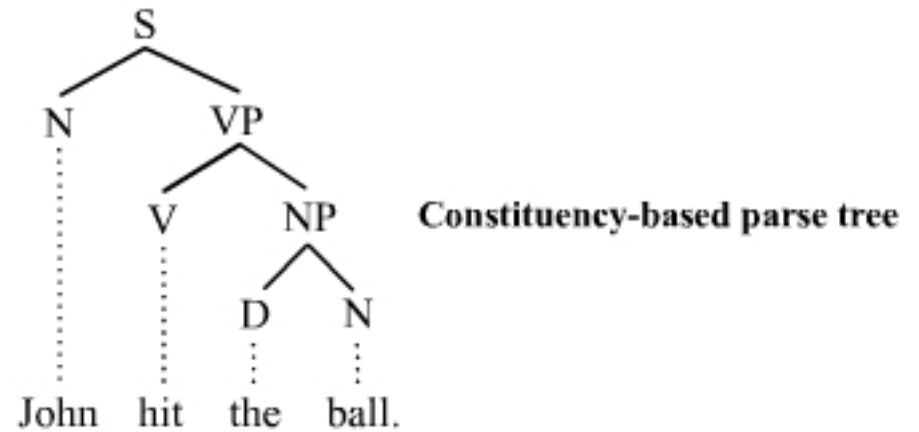
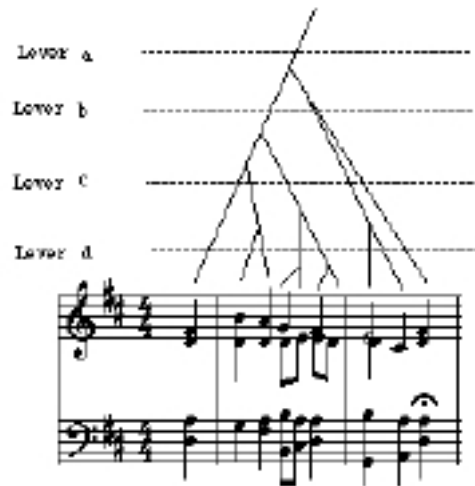
See the music of Iannis Xenakis

http://en.wikipedia.org/wiki/Iannis_Xenakis

(Kronengold)

http://en.wikipedia.org/wiki/Hyperprism_%28Var%C3%A8se%29

GTTM

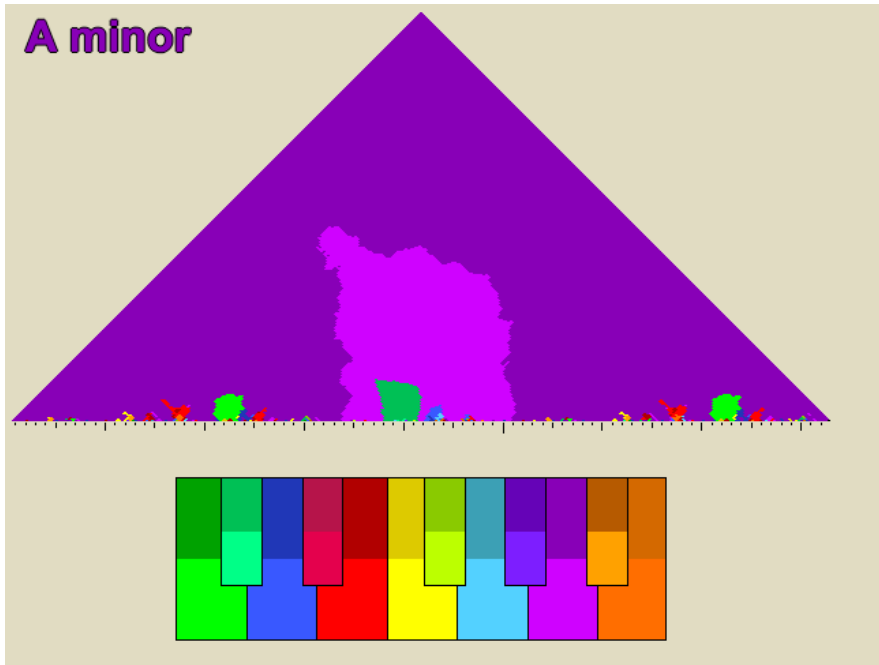


http://en.wikipedia.org/wiki/Parse_tree

http://en.wikipedia.org/wiki/Generative_theory_of_tonal_music

Keyscapes

Graphical display of harmonic structure



Chopin mazurka in A minor Op. 67, No. 4

<https://www.youtube.com/watch?v=AcxZRI6aews>

A major: 1:18

A minor: 2:10

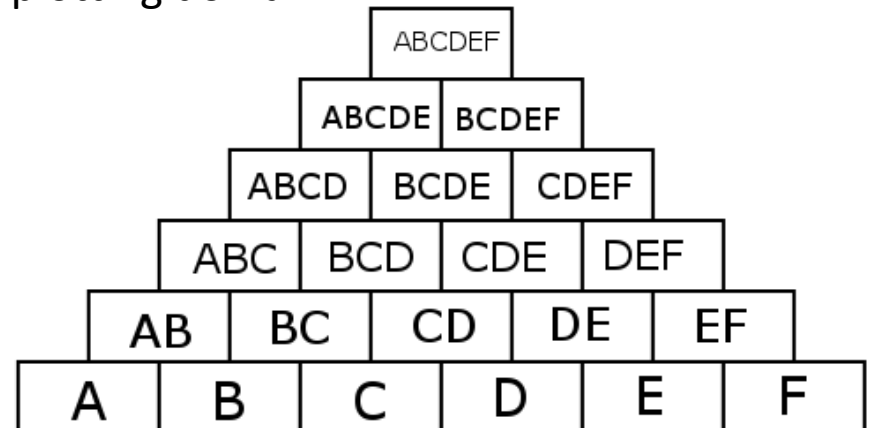
Landscape:

background
large-scale structures
middleground
small-scale structures
foreground
surface features



An Orchard c1896 Henri Rousseau

Scape plotting domain:



Computational Key Identification



<http://extras.humdrum.org/man/keycor>

Computational Key Identification



Pearson correlation:

$$r(x, y) = \frac{\sum_n (x_n - \bar{x})(y_n - \bar{y})}{\sqrt{\sum_n (x_n - \bar{x})^2 \sum_n (y_n - \bar{y})^2}}$$

Krumhansl-Schmuckler
key-finding algorithm:

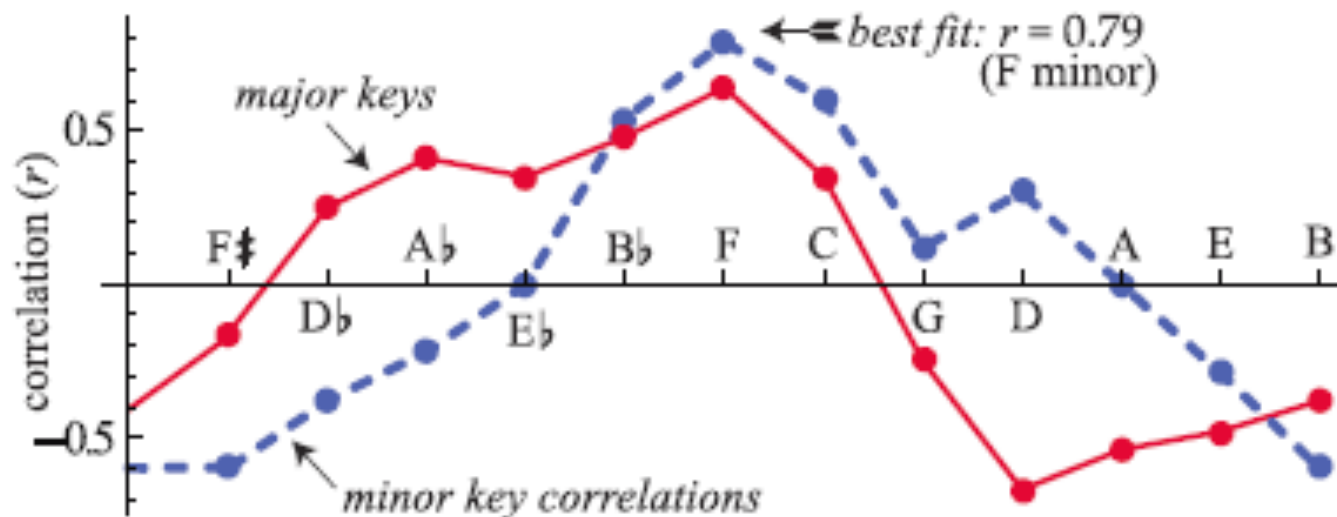
$$\text{key}_k = \arg \max_k r(x, y_k)$$

Computational Key Identification



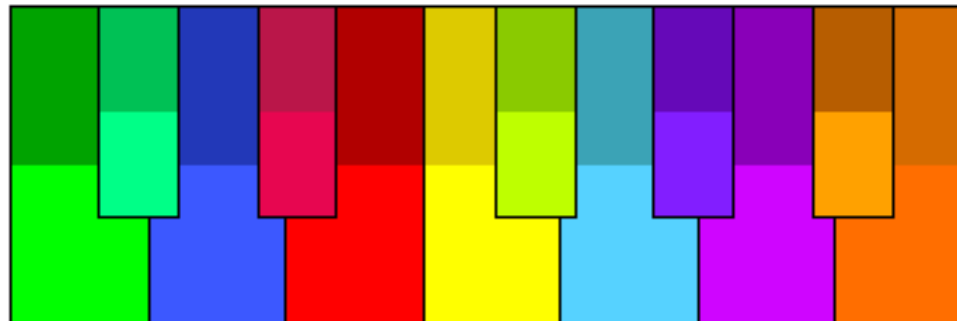
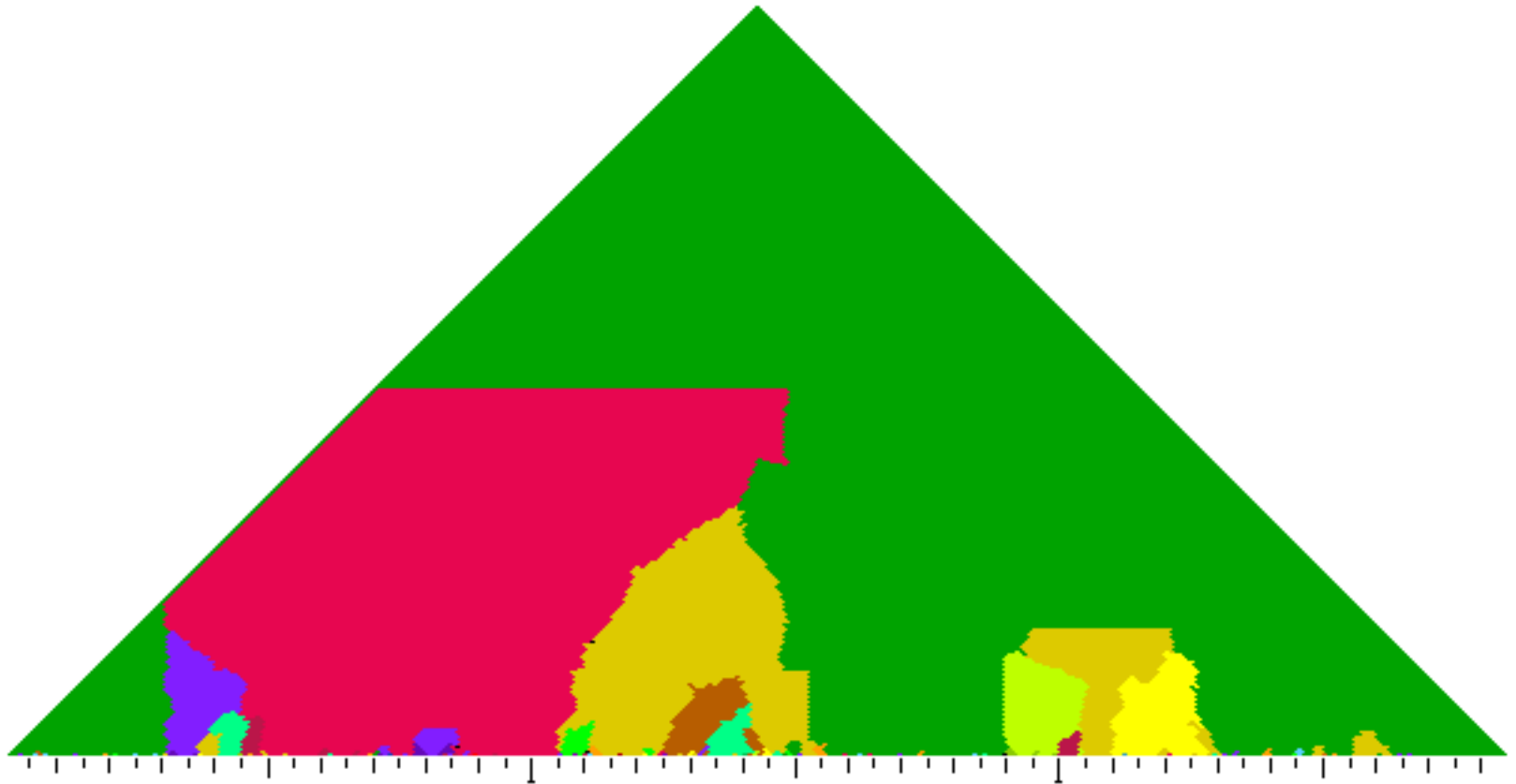
pitch-class counts
(duration weighted):

C: 8 ♩	D \sharp /E \flat : 0	F \sharp /G \flat : 0	A: 0
C \sharp /D \flat : 0	E: 2 ♩	G: 5 ♩	A \sharp /B \flat : 5 ♩
D: 0	F: 11 ♩	G \sharp /A \flat : 7 ♩	B: 2 ♩

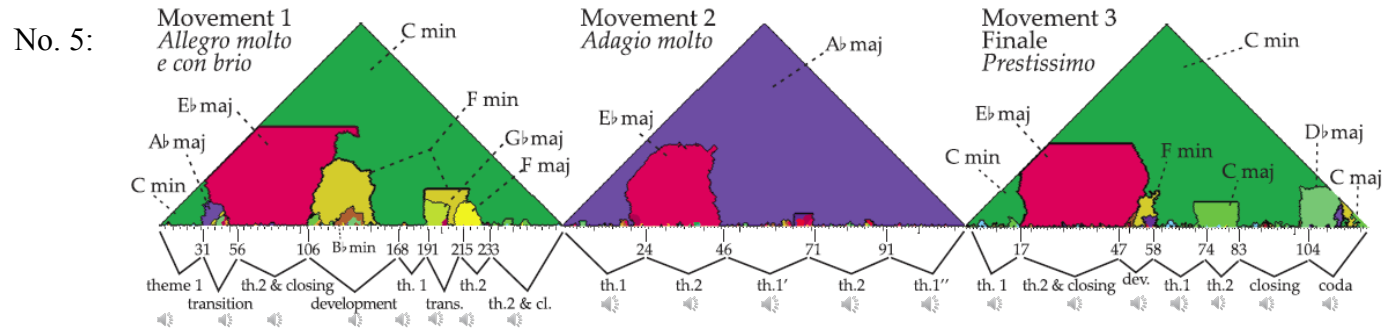


pitch-class histogram: $x = (8, 0, 0, 0, 2, 11, 0, 5, 7, 0, 5, 2)$
 major key prototype: $y_M = (2, 0, 1, 0, 1, 1, 0, 2, 0, 1, 0, 1)$
 minor key prototype: $y_m = (2, 0, 1, 1, 0, 1, 0, 2, 1, 0, 1, 0)$

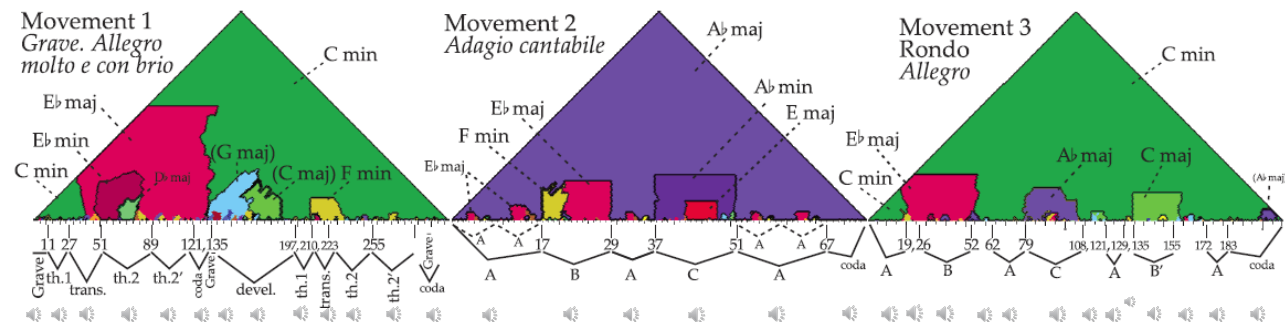
Beethoven Piano Sonata #5 mvmt 1



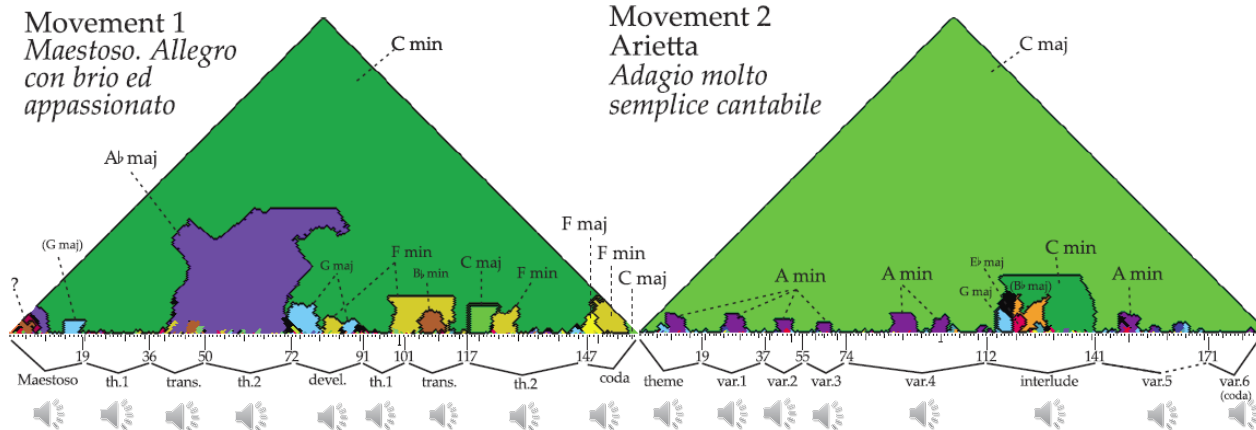
Other C-Minor Beethoven Sonatas



Piano Sonata no. 8 in C minor, op. 13 ("Pathétique")



piano sonata no. 32



Form Visualization/Analysis

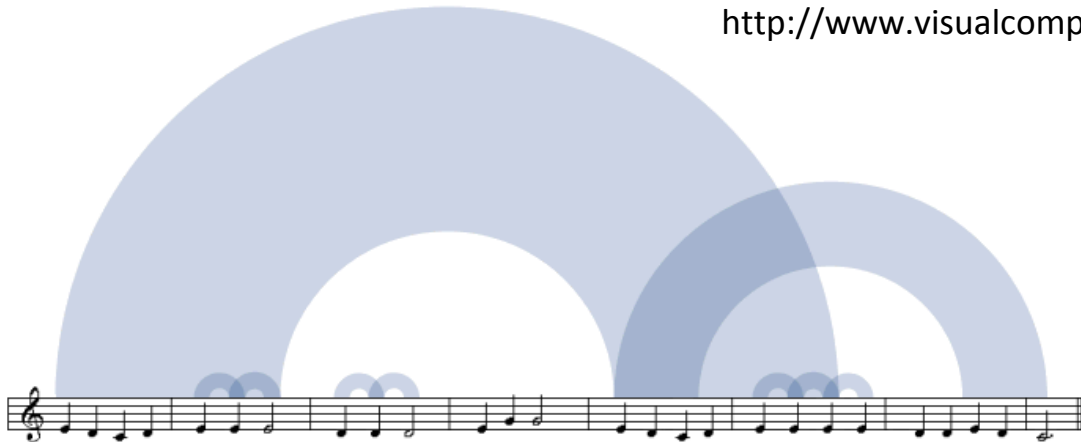
<http://www.bewitched.com/song.html>

<http://hint.fm/papers/arc-diagrams.pdf>

Martin Wattenberg



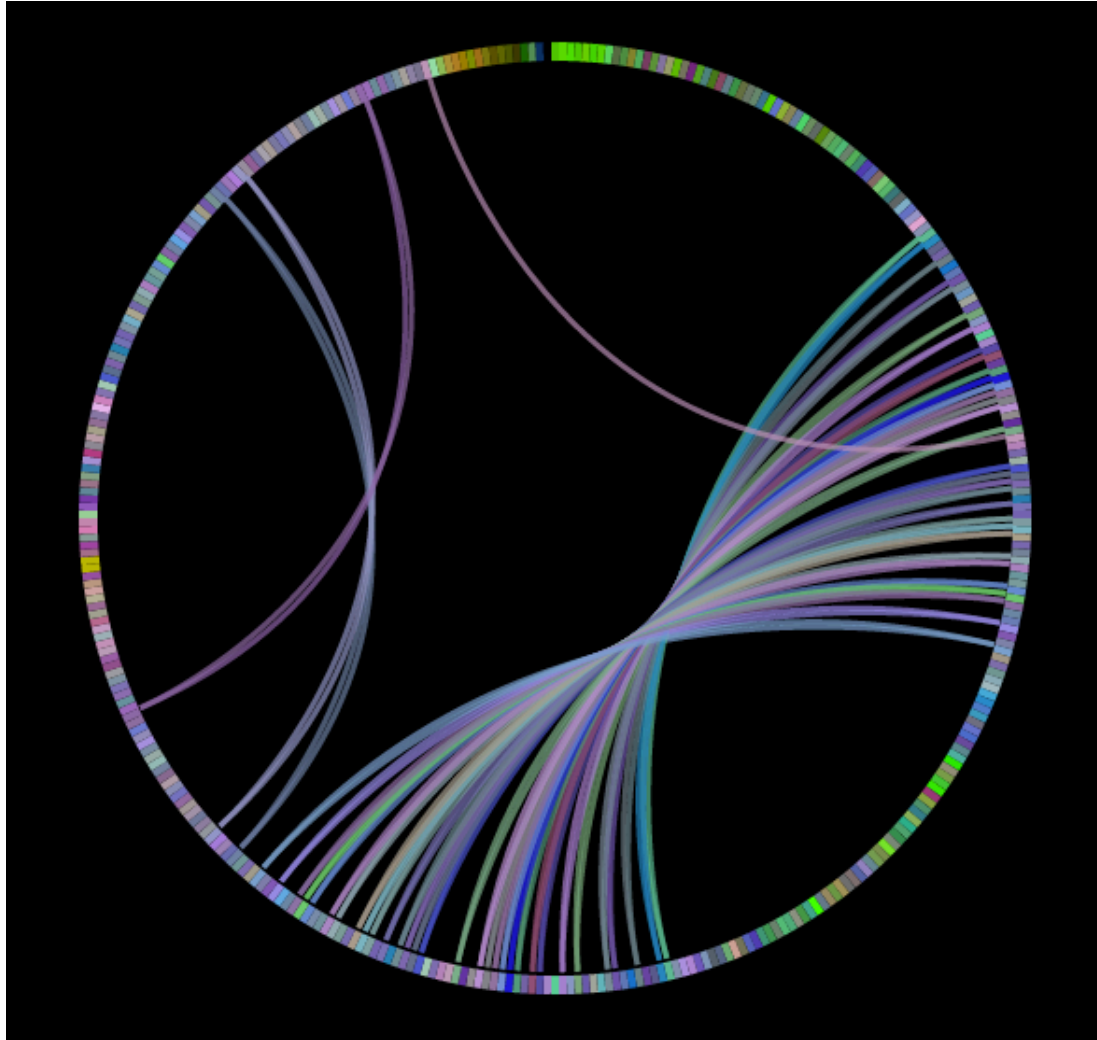
<http://www.visualcomplexity.com/vc/index.cfm?method=Arc%20Diagrams>



Infinite Jukebox

<http://labs.echonest.com/Uploader/index.html?trid=TRORQWV13762CDDF4C>

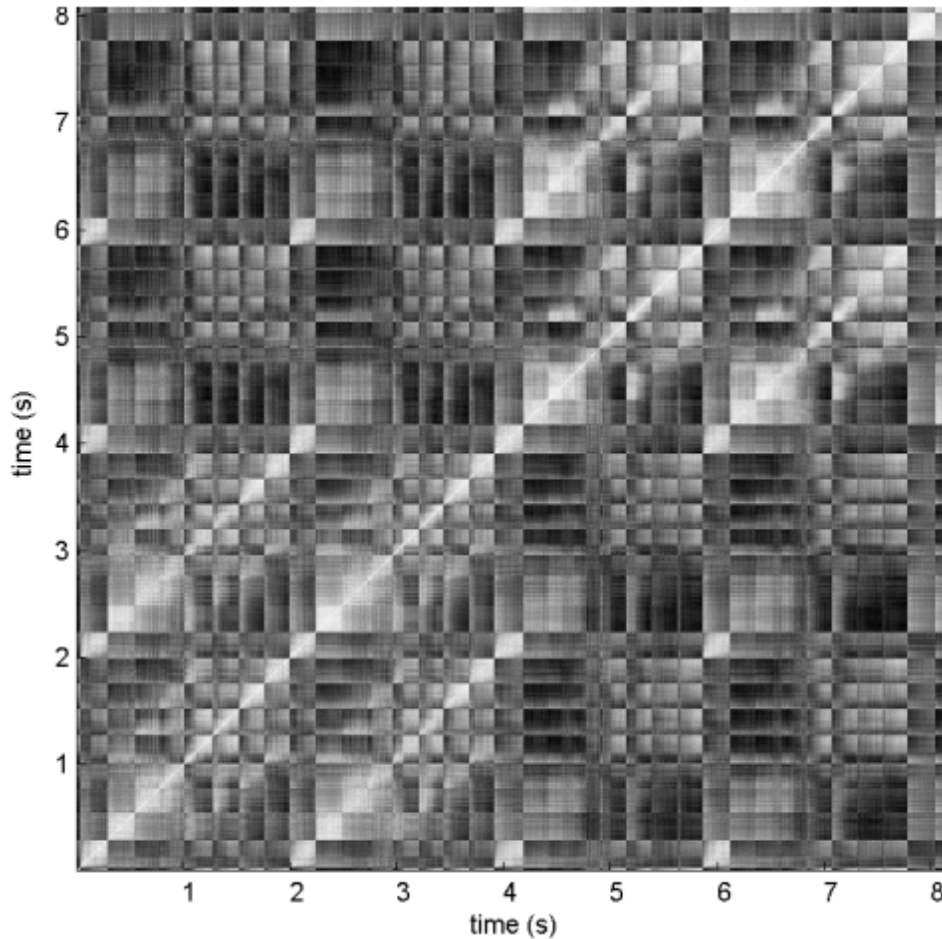
Paul Lamere



Similarity Matrix

Jonathan Foote

<http://www.fxpall.com/publications/visualizing-musical-structure-and-rhythm-via-self-similarity.pdf>



J.S. Bach WTC 1: Prelude #1 in C major

